

Highlights from CARB's Study of Emissions from Transit Buses

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Study Objectives

Take a “snap-shot” of in-use fleet (not a fleet average) and...

- Assess driving cycle effects
- Characterize types and amounts of several toxic substances
- Investigate total PM and ultrafine particle (<100 nm) emissions



CARB Initial Study Results

- CNG bus without after-treatment had measurable and in some cases higher levels of some toxic, nanoparticle (<50 nm), and mutagen (modified Ames assay) emissions relative to similar ULSD-fueled diesel bus with after-treatment (DOC and catalyzed DPF)

CARB Follow-up Study

- Investigate effectiveness of oxidation catalyst control for CNG transit bus application



Scope and Methods

- Cycles: Idle, 55mph Cruise, CBD, NYBC, UDDS
- PM: filters and MOUDI
- Total HC's: heated FID
- NO_x, NO₂: chemiluminescence
- CO, CO₂: NDIR
- Carbonyls: DNPH cartridges/HPLC
- Metals: teflon filter/XRF
- Mutagenicity: filter+vapor traps, modified Ames assay
- PAH's: filter+vapor traps, GC-MS
- EC/OC: quartz filter/TOR
- VOC's and NMHC: Tedlar bag/GC
- PM number/size: SMPS & ELPI @ mini-diluter and SMPS @ CVS



CARB's Chassis Dynamometer Laboratory



Test Vehicles



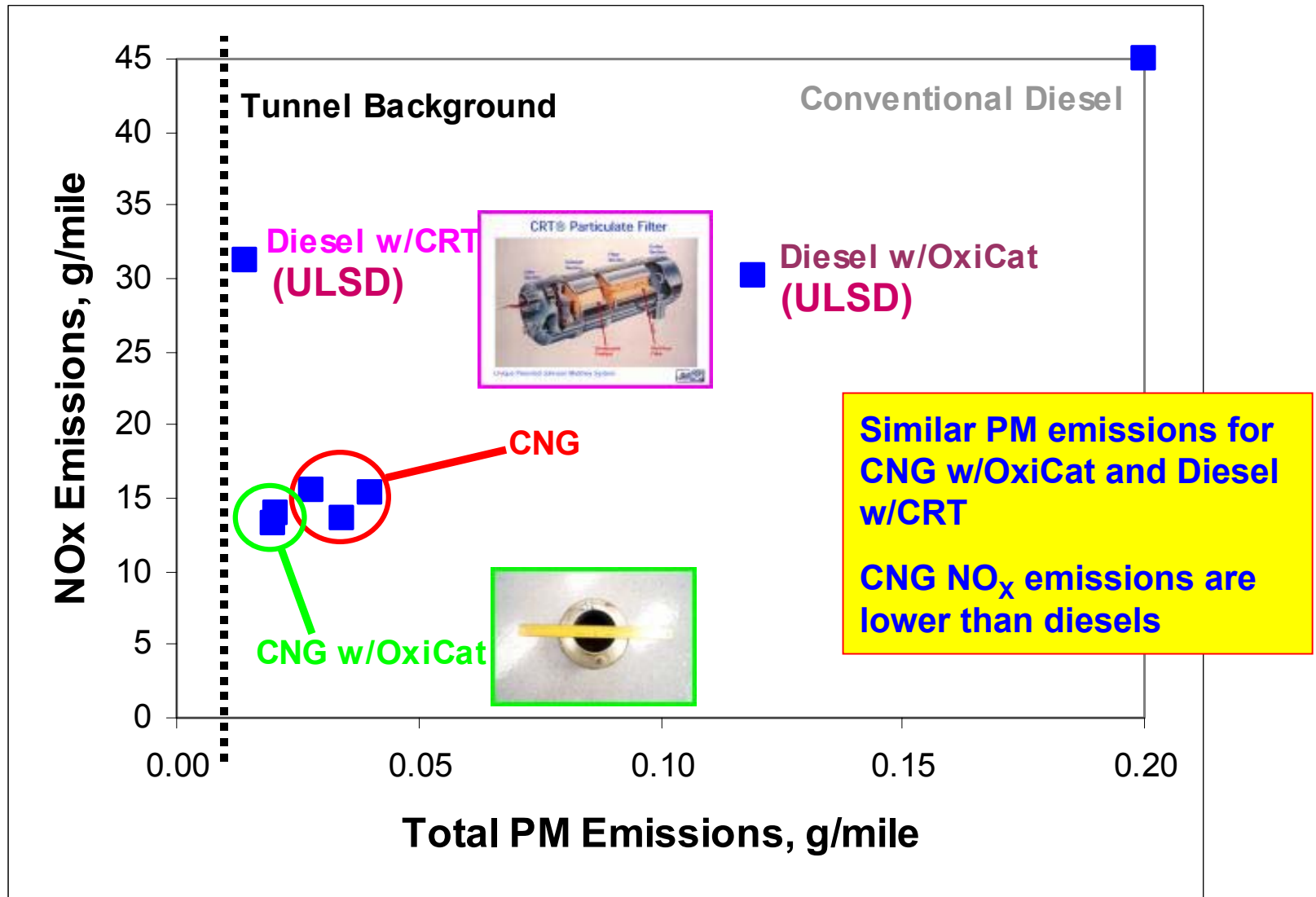
	DDC	Cummins Westport	DDC
Data label	Diesel Baseline and Diesel CRT	Cummins w/Oxi Cat	DDC CNG-3
Vehicle	#3007	#134	#5300
Fleet	Los Angeles MTA	Omnitrans	Los Angeles MTA
Chassis	New Flyer	New Flyer	New Flyer
Capacity	40 passenger	40 passenger	40 passenger
Fuel	ECD-1	CNG	CNG
Engine	Series 50	Cummins Westport C Gas Plus	Series 50 G
Model year	1998	2001	2000
After-treatment	DOC and DPF	Oxidation Catalyst (OC)	OEM* and OC**

**OEM configuration = no after-treatment*

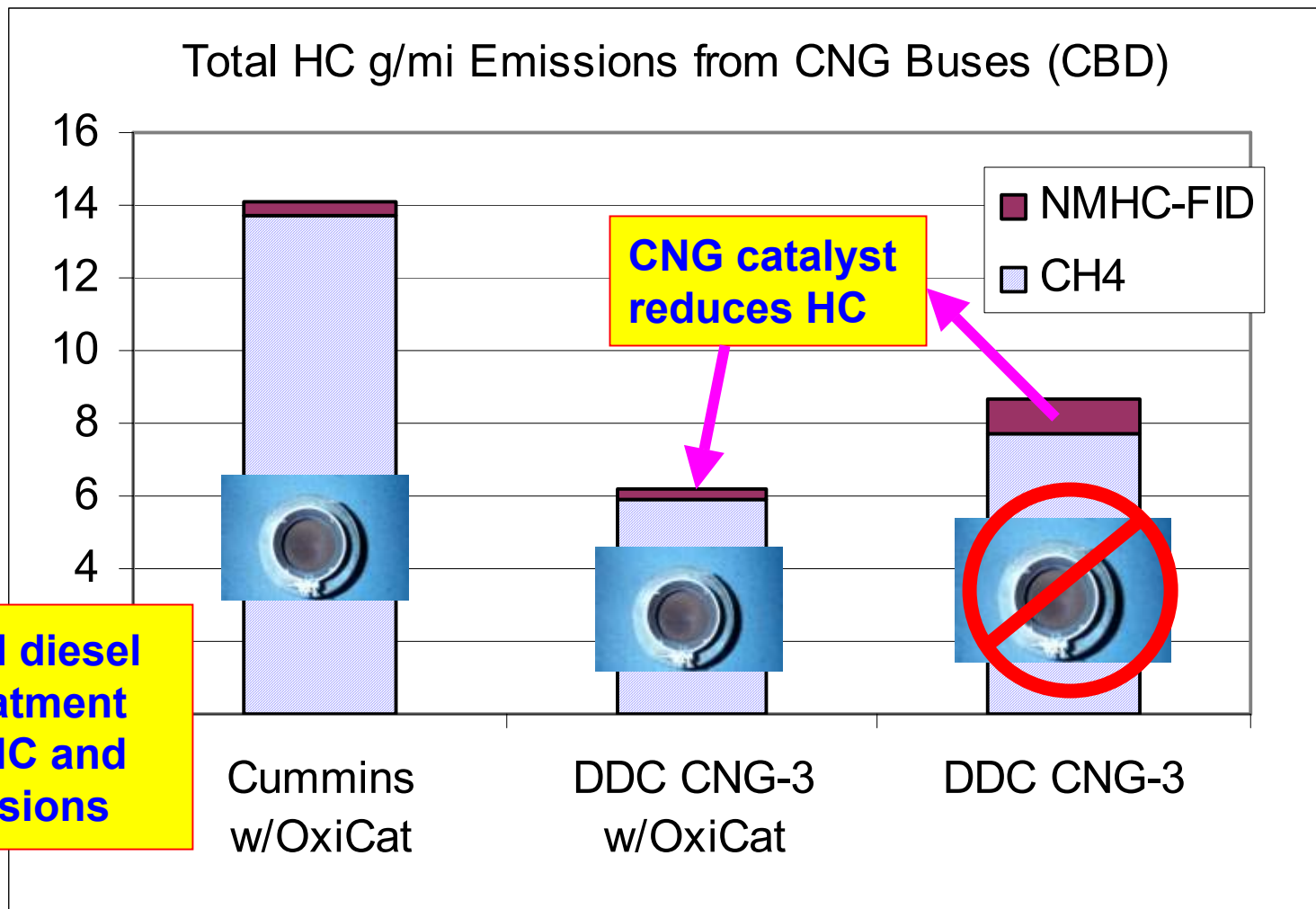
***First DDC-S50G w/OxiCat on New Flyer chassis bus*



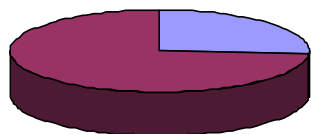
Average NO_x and PM Emissions - CBD



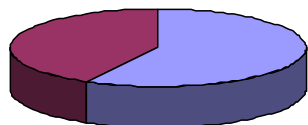
Average HC CNG Bus Emissions - CBD



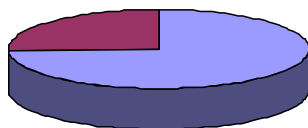
Diesel PM Composition Depends on Cycle



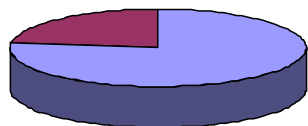
IDLE



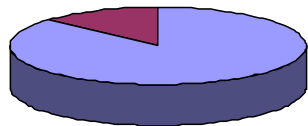
**55 mph
Cruise**



CBD



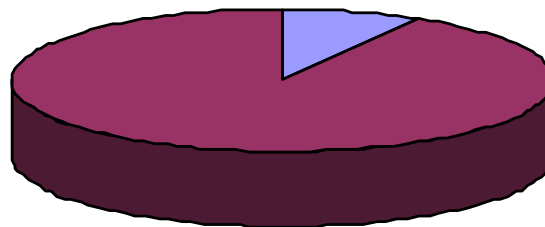
UDDS



NYBC

CNG (CBD)

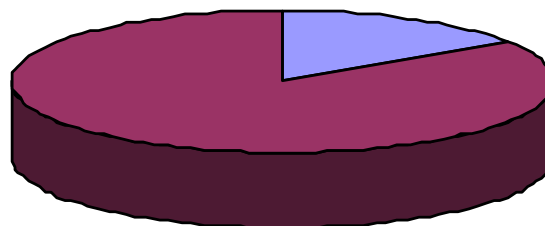
**CNG w/OxiCat
results PENDING**



■ Elemental Carbon
■ Organic Carbon

**CNG and Diesel w/CRT
PM composition is
primarily OC for all
cycles**

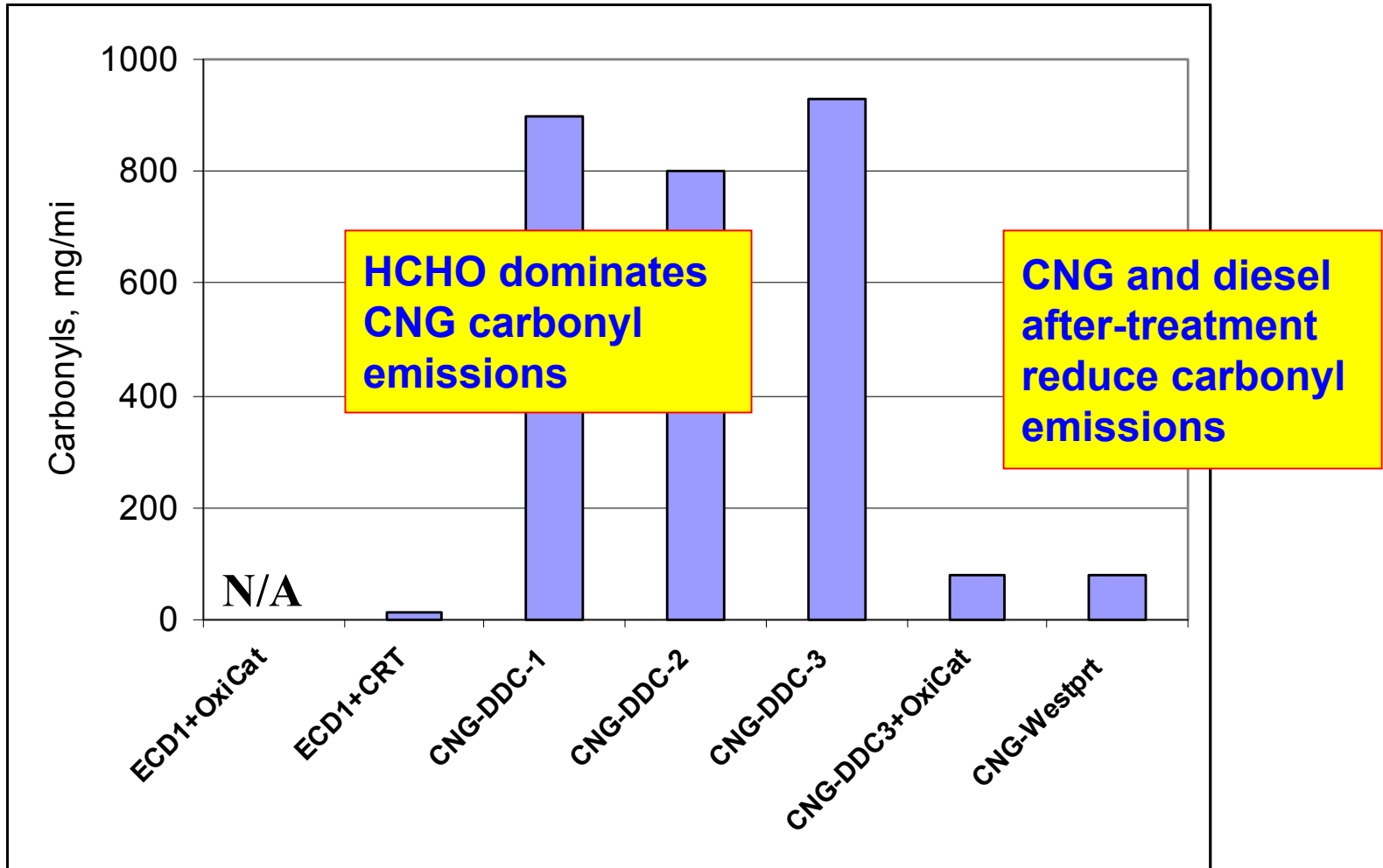
Diesel CRT (CBD)



■ Elemental Carbon
■ Organic Carbon



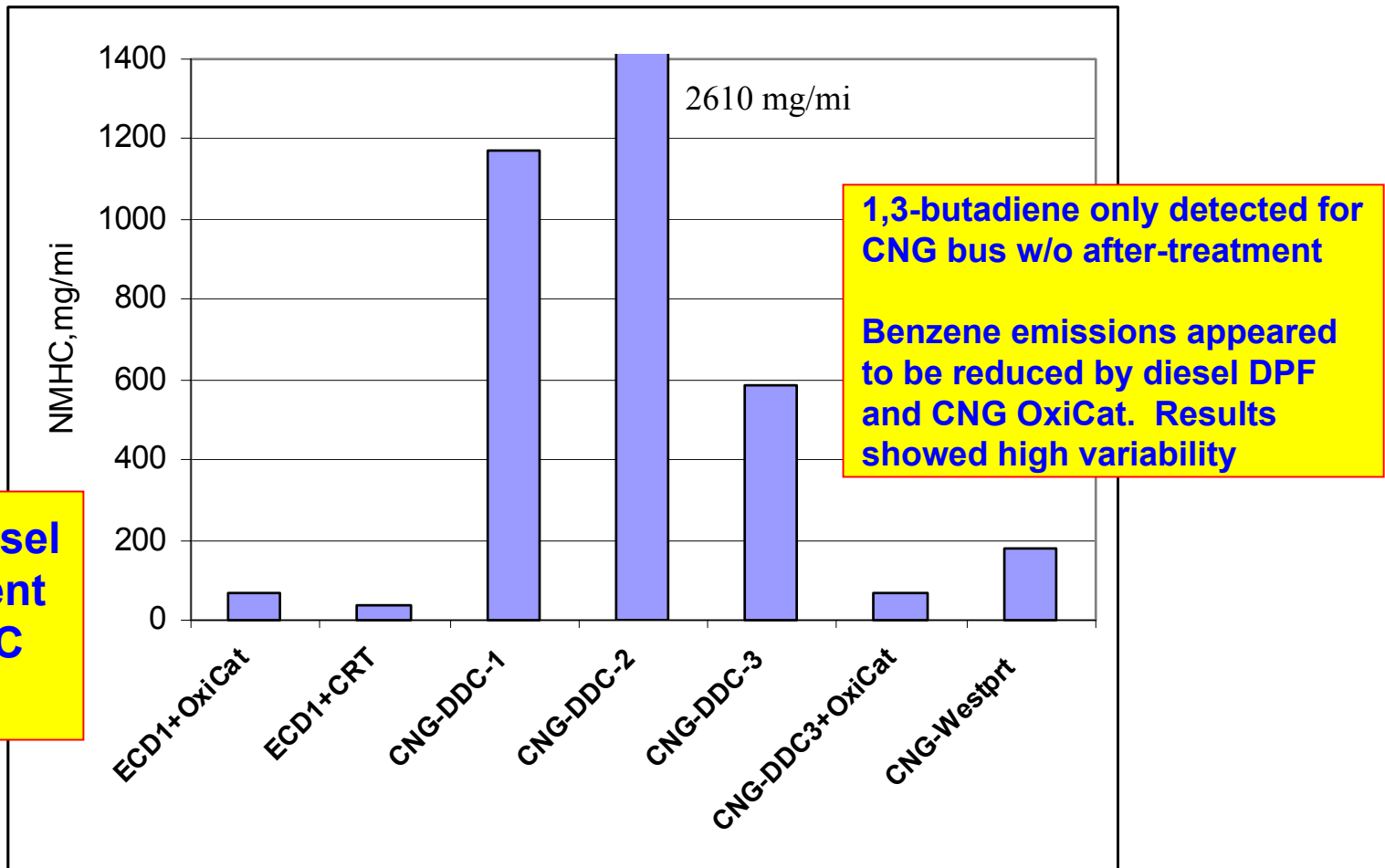
Average Carbonyl Emissions - CBD



Note: CNG-DDC-1,-2,-3 = same bus tested three times



Average NMHC-GC Emissions - CBD

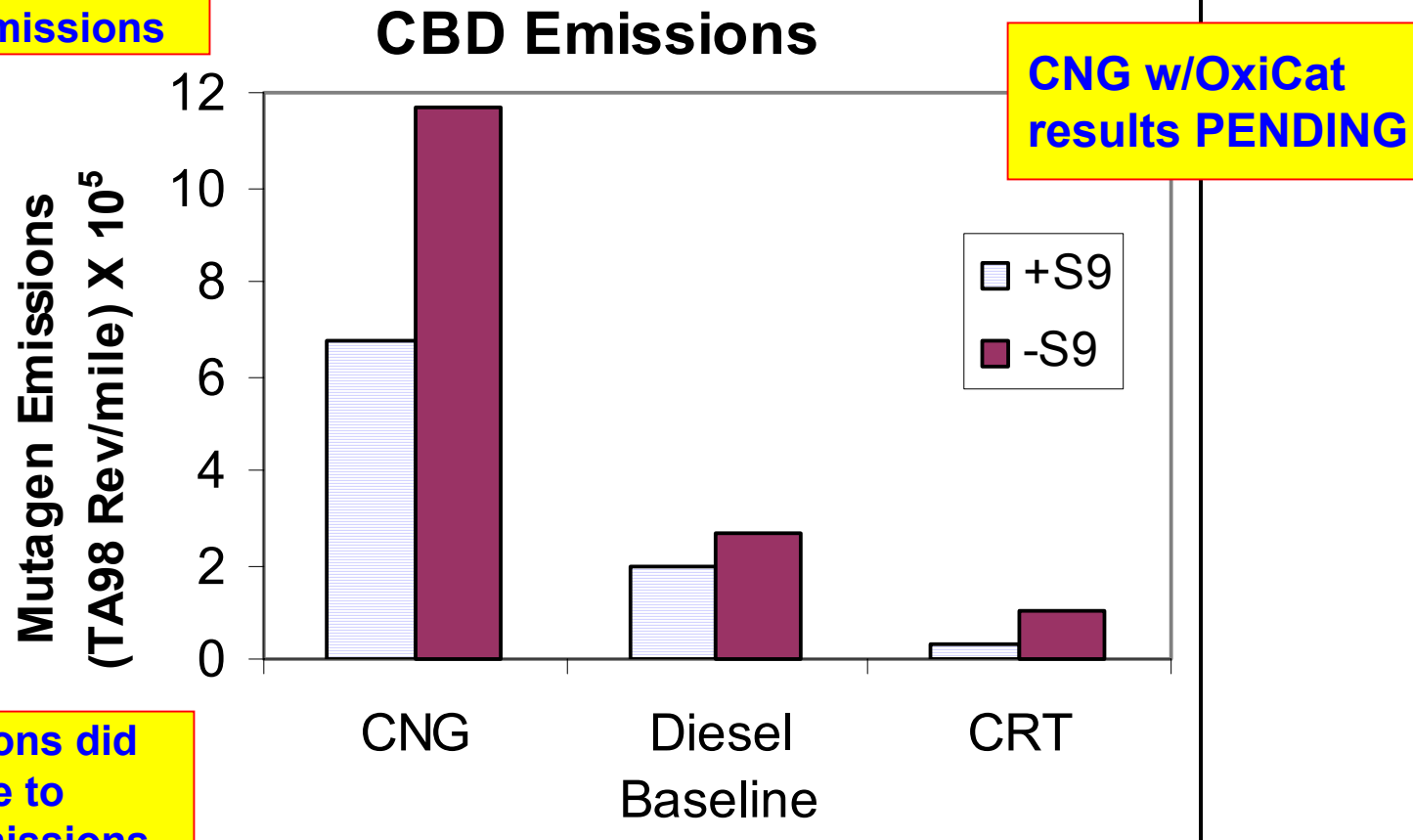


Note: CNG-DDC-1,-2,-3 = same bus tested three times



Average Mutagen Emissions - CBD

Conventional diesel
has highest
mutagen emissions



PAH emissions did
not correlate to
mutagen emissions



Final Remarks

- Current CNG-fueled (with or without after-treatment) and catalyzed DPF-equipped diesel transit buses are superior to conventional diesel buses in terms of NO_x and PM.
- All emissions results showed cycle dependence.
- “Clean” buses pose significant challenges to current sampling methodologies.
- No “clean” technology is clearly superior to other. Both can be improved.
- Catalyzed DPF for diesel applications and oxidation catalyst for CNG applications appear to offer significant benefits.

